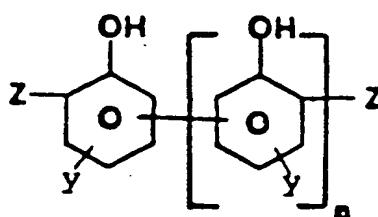




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(54) Title: BIOCATALYTIC PROCESS FOR PREPARING PHENOLIC RESINS



(I)

(57) Abstract

In a process for the preparation of a phenolic resin, a phenol is reacted with a peroxidase or an oxidase enzyme and a peroxide in an organic solvent containing medium to generate phenolic radicals which react to form phenolic resins and, more particularly, formaldehyde-free resins of formula (I), where n is an integer greater than or equal to 2, the phenolic units of the resin are directly bonded to one another through positions *ortho* or *para* to the hydroxyl group, Y is present at a position *meta* or *para* to the hydroxy group and is selected from the group consisting of an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, an allyl group, a carboxyl group of the formula -COOR, where R is a hydrogen atom, an alkyl group or a phenylalkyl group, an amino group of the formula -NR₁R₂ where R₁ and R₂ are the same or different and represent a hydrogen atom or an alkyl group, and Z is a hydrogen atom, an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, or a -COOR group, or Z in conjunction with the adjacent *meta* position forms a condensed benzene ring; or a metal-modified, formaldehyde-free phenolic developer resin obtained by reacting said developer resin with a metal salt; the resins are useful as developers in forming colored images by reaction with substantially colorless electron-donating compounds.

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BIOCATALYTIC PROCESS FOR PREPARING PHENOLIC RESINS

Background of the Invention

The present invention relates to an improvement in a process for preparing phenolic resins through biocatalytic oxidation of phenols wherein the oxidation reaction is performed in an organic solvent and, more particularly, in an aqueous-organic solvent system.

The present invention also relates to phenolic developer resins and more particularly, to developer resins which are useful in recording materials such as carbonless paper where they function as electron acceptors and react with substantially colorless electron donating compounds to produce a visible image.

As background to the process for the preparation of the phenolic resins, Alberti and Klibanov, BIOLOGICAL DETOXICATION, Chapter 22, Peroxidase for Removal of Hazardous Aromatics from Industrial Wastewaters, (1982), discloses that phenols can be removed from wastewaters as high molecular weight polymers by the action of peroxidase enzymes. The disclosed method relies on the ability of peroxidase enzyme to catalyze, with hydrogen peroxide, the oxidation of a variety of phenols and aromatic amines. Phenolic and aromatic amine free radicals are generated, which diffuse from the active center of the enzyme into solution, and polymerize to polyaromatic products. These high molecular weight polymers are water-insoluble and can be readily separated by filtration.

As background to the phenolic developer resins, recording materials utilizing developer resins to produce colored images from colorless or substantially colorless materials are well-known.

5 Specific examples of such recording materials include pressure-sensitive carbonless copying paper, heat-sensitive recording paper, electro-thermographic recording paper, and the like. They are described in more detail in U.S. Patent Nos.
10 2,712,507; 2,730,456; 2,730,457; 3,418,250;
3,432,327; 3,981,821; 3,993,831; 3,996,156;
3,996,405 and 4,000,087, etc. A photographic
material has been developed which utilizes this
15 method for forming colored images. See, for ex-
ample, U.S. Patents Nos. 4,399,209 and 4,440,846
to The Mead Corporation.

Much research has been directed to developing new and improved developers for use in the aforementioned recording materials. The preferred 20 developers are principally phenol derivatives and phenolic resins. Phenols, biphenols, methylene bis-diphenols, phenol-formaldehyde novolak resins, metal processed novolak resins, salicylic acid derivatives and salts are representative examples
25 of the phenolic developers that have been used. See U.S. Patent No. 3,934,070 to Kimura teaching salicylic acid derivatives; U.S. Patent 3,244,550 to Farnham teaching biphenols, diphenols, and resinous products containing them; and U.S. Patent
30 No. 3,244,549 to Farnham teaching phenol derivatives. Representative examples of phenol-formaldehyde condensates previously used in the art are described in numerous patents, including U.S. Patent No. 3,672,935.

5 Among the color developers, phenol-formaldehyde condensates have been widely used because they exhibit excellent color development, good coating properties (rheology) and good water resistance. While phenolformaldehyde condensates are advantageous color developers, certain questions have arisen regarding their use in recording materials. Because they are prepared from formal-dehyde, concern exists that they may be unsafe from both the standpoint of their manufacture and their use in recording materials.

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Summary of the Invention

An object of the present invention is to provide an improved process for preparing phenolic resins for commercial use.

Another object of the present invention is to provide an improved process for preparing phenolic resins in higher yields.

Still another object of the present invention is to provide a process for preparing phenolic resins which facilitates recovery of the peroxidase enzyme.

Another object of the present invention is to provide a novel phenolic resin and, more particularly, a formaldehyde-free, phenolic resin for use as a color developer in the aforementioned recording materials.

The developer resins of the present invention are preferably prepared by free radical addition polymerization of a phenol using a peroxide-peroxidase enzyme system. The oxidation of phenol by horseradish peroxidase and hydrogen peroxide is known, although previously it has been

performed in aqueous systems. See Danner et al., "The Oxidation of Phenol and Its Reaction Product by Horseradish Peroxidase and Hydrogen Peroxide," Archives of Biochemistry and Biophysics, 156, 5 759-763 (1973); and Sanders et al., "Peroxidase," Butterworth, Inc., Washington, D.C. (1964). It has been found, however, that the reaction proceeds in higher yields and provides a higher molecular weight product if it is performed in an organic and, more preferably, an organic-aqueous solvent system.

In accordance with the present invention, biocatalytic oxidation of the phenol is carried out in an organic solvent and, more particularly, 15 in an organic-aqueous solvent medium. It has been found that the oxidative polymerization reaction proceeds in higher yields and is capable of providing a higher molecular weight product when it is performed in these solvent systems.

One process in accordance with the present invention comprises preparing separate solutions of the phenol, enzyme, and peroxide, and mixing them. The phenol is typically dissolved in an organic solvent, and the enzyme and peroxide are 20 typically dissolved in water. The organic-aqueous solvent system is formed by mixing the solutions. The solutions may be gradually added to a common reaction vessel, or the solutions of the phenol and the enzyme may be pre-mixed and the peroxide, 25 neat or in solution, gradually added thereto.

Embodiments of the present invention are also envisioned in which the enzyme is provided on a solid support and the process is carried out on a

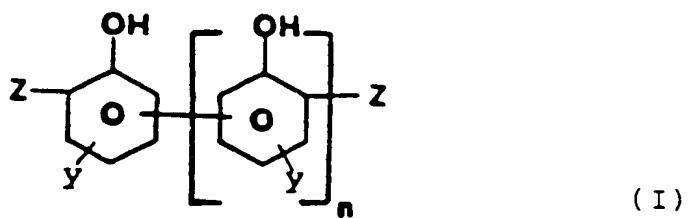
batch or continuous basis. In any process, it is important to limit the rate of addition of the peroxide since excess peroxide inhibits the reaction.

5 The organic solvent may be water miscible or water immiscible. If the solvent is water miscible, the reaction proceeds in the solution phase. If the solvent is water immiscible, a dispersion is formed upon mixing the phenol and the enzyme solutions and the reaction proceeds at the interface. The resin is recovered from the solvent phase and the enzyme can be recovered from the aqueous phase and re-used.

10 Accordingly, the present invention provides a process for preparing a phenolic resin which comprises reacting a phenol with a peroxidase or an oxidase enzyme and a peroxide in an organic solvent containing medium to generate phenolic radicals which react to form a phenolic resin.

15 More particularly, the present invention provides a process for preparing a phenolic resin which comprises preparing a solution of a phenol in a water miscible or a water immiscible solvent and an aqueous solution of an oxidase or peroxidase enzyme, mixing said solutions and adding a peroxide thereto, wherein said phenol reacts with said enzyme and said peroxide and generates phenolic radicals and said radicals react to form a phenolic resin.

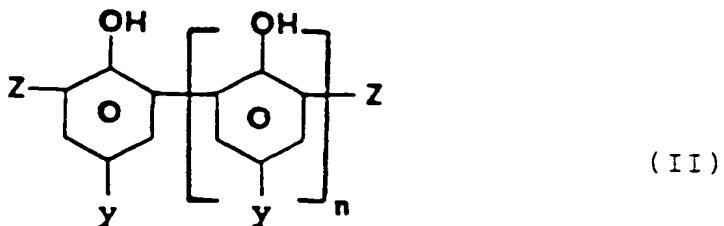
20 A developer resin capable of reacting with an electron-donating color precursor and producing a visible image is represented by the formula (I):



(I)

where n is greater than or equal to 2, the phenolic units are bonded to one another through the ortho and/or para positions, Y is present at the meta or para position and is selected from the group consisting of an alkyl group, a halogen atom (e.g., fluorine, chlorine, or bromine), an aryl group, a phenylalkyl group, an allyl group, a group of the formula -COOR where R is a hydrogen atom, an alkyl group or a phenylalkyl group, an amino group of the formula -NR₁R₂ where R₁ and R₂ are the same or different and represent a hydrogen atom or an alkyl group, and Z is a hydrogen atom, an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, a -COOR group, or Z in conjunction with the adjacent meta position represents a condensed benzene ring which may be substituted or unsubstituted, and derivatives thereof obtained by reacting said developer resin with a metal salt.

In accordance with a more preferred embodiment of the invention, the developer resin is represented by the formula (II):



(II)

where n, Y and Z are defined as in formula (I).

Another embodiment of the present invention relates to a recording material comprising a support, a layer of microcapsules containing in the internal phase a substantially colorless electron-donating color precursor on one surface of said support, and an electron-accepting color developer material present on the same surface of said support as said microcapsules; on the opposite surface of said support as said microcapsules, or on the surface of a separate support, wherein said developer material is a phenolic resin of the formula (I) above and, more preferably, of the formula (II).

Still another embodiment of the invention is a developer sheet having the aforementioned developer resin on the surface thereof.

Other objects and advantages of the present invention will become apparent from the following description and the appended claims.

Detailed Description of the Invention

Peroxidase and oxidase enzymes are known in the art and are commercially available. The most typical example of a peroxidase enzyme useful in the present invention is horseradish peroxidase, but other peroxidases such as chloroperoxidase (and other haloperoxidases), lactoperoxidase, and bacterial peroxidases are also useful. In addition, oxidase enzymes such as fungal laccase and tyrosinase may be useful.

The amount of the enzyme used to make the phenolic resin will depend on its activity. The enzyme functions as a catalyst and is not consumed

in the reaction. For commercially available enzymes, the enzyme can be reacted in an amount of about 10 milligrams to 5 grams per 100 grams phenol.

5 In accordance with the preferred embodiment of the invention, the enzyme is dissolved in water and added to a solution of the phenol. The enzyme solution concentration is not particularly critical. It typically ranges from about 10 to
10 365 mg per liter. It is generally desirable to prepare an enzyme solution at a concentration such that it can be added in an approximately equal volume to the solution of the phenol, but this may vary.

15 The oxidizing agent used in generating the free radicals is typically hydrogen peroxide, but other peroxides are useful. Examples of other potentially useful peroxides include methyl peroxide, ethyl peroxide, etc.

20 The peroxide is reacted in an amount of about 0.1 to 2.5 moles per 100 grams phenol and, more typically, about 0.1 to 0.5 moles per 100 grams phenol. Depending upon the nature of the oxidizing agent, it is reacted neat or as a solution. The preferred oxidizing agent, hydrogen peroxide, is dissolved in water. Its concentration may range from about 0.001 to 1.0 mol per liter.

25 30 The phenol can be reacted in an aqueous or a non-aqueous solvent to produce the resin, but a preferred solvent is an organic-aqueous solvent system including water and a water-miscible or water-immiscible solvent. Representative examples of useful water-immiscible solvents include

5 hexane, trichloroethane, methyl ethyl ketone,
10 ethyl acetate, and butanol. Examples of useful
15 water-miscible solvents include ethanol, methanol,
20 dioxane, tetrahydrofuran (THF), dimethyl formamide,
25 and acetone. The reaction is typically carried
30 out at phenol concentrations of about 1 to 100 g
35 per 100 ml solvent. Solvent-aqueous based systems
40 are particularly preferred because they provide
45 better yields and facilitate recovery and recycling
50 of the enzyme.

5 As indicated above, a number of different
10 procedures may be used to react the phenol. Sol-
15 utions of the phenol, enzyme, and peroxide may be
20 individually prepared and metered into a reaction
25 vessel, or solutions of the phenol and enzyme may
30 be pre-mixed and the peroxide gradually added
35 thereto. Alternatively, the enzyme and phenol may
40 be dissolved in a common solvent and the peroxide
45 added. Those skilled in the art will appreciate
50 that a number of reaction/mixing sequences are
55 useful provided that the peroxide is added at a
60 controlled rate which is approximately equal to
65 the rate at which it is consumed such that the
70 concentration of the peroxide does not build to a
75 level at which it undesirably inhibits the
80 reaction.

5 The organic-aqueous system formed upon
10 mixing the phenol, enzyme and peroxide may contain
15 water and an organic solvent in a volumetric ratio
20 (water:organic) in the range of 1:10 to 10:1, more
25 typically, 1:2 to 2:1, and most typically, about
30 1:1. The most preferred ratio will vary with the
35 nature of the phenolic monomer(s) that is(are)
40 polymerized.

The reaction of the phenol proceeds at room temperature, but temperatures of about 0 to 40°C can be used. The enzymes are temperature sensitive and can lose their activity if the re-action temperature becomes too high. For example, 5 temperatures in excess of about 60°C render horse-radish peroxidase inactive. However, some latitude exists, depending upon the solvent system which is used. Certain solvents can stabilize the enzyme 10 and thereby permit the use of higher temperatures.

The activity of the enzyme is pH dependent. The reaction is preferably carried out at a pH in the range of 4 to 12 and, more preferably, 4 to 9. Buffers can be used to maintain pH, but are 15 not usually required. One example of an useful buffer is a potassium phosphate buffer.

A pH is selected at which the enzyme is highly active. This will vary with the enzyme and its source. The most preferred pH for Sigma Type 20 I peroxidase (a product of Sigma Chemical Company) is about 6.0. Using this enzyme, deionized water can be used to form the solvent system.

While reference is herein made to the bulk pH of the reaction system, those skilled in 25 the art will appreciate that it is the pH in the micro-environment of the enzyme that is critical. It has been found that enzyme recovered at pH outside the aforementioned ranges is inactive or less active; whereas, if the same enzyme is redi-30 solved at a pH within the aforementioned range and recovered, it is active. Thus, where the phenol is dissolved in a water immiscible solvent and the enzyme solution is dispersed in the solution of

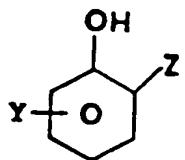
the phenol, it is the pH of the enzyme solution which is critical.

5 Phenolic resins prepared in accordance with the present invention are useful in a variety of applications depending on the nature of the phenol and the molecular weight of the resin. The resins are often mixtures of dimers, trimers, and very high molecular weight oligomers. Usually, 10 the major part of the resin, i.e., greater than 50% by weight of the resin, is trimer or higher molecular weight compounds.

15 The molecular weight of the phenolic resin can be adjusted depending upon its particular end use. In one embodiment, the process of the present invention provides a phenolic resin which is useful as a developer in recording materials such as carbonless copy paper, heat-sensitive recording paper, electrothermographic recording paper and the like. The phenols used in developer 20 resins are preferably para-substituted. The resins may range from about 500 to 5000 in molecular weight.

25 In another embodiment, the process of the present invention provides a phenolic resin which is useful as an adhesive. The phenols used in adhesives need not be para-substituted. The resins typically range from about 1000 to 15,000 in molecular weight.

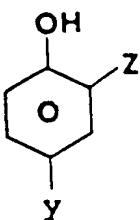
30 Phenols which are preferred for use in the present invention are represented by the Formula (III):



wherein Y and Z are selected from the group consisting of a hydrogen atom, a halogen atom, an alkyl group, an alkoxy group, an aryl group, an allyl group, a phenylalkyl group, a -COOR group where R represents a hydrogen atom or a lower alkyl group, and a -NR₁R₂ group, where R₁ and R₂ represent a hydrogen atom, an alkyl group, or a phenylalkyl group or Z in conjunction with the adjacent meta position forms a condensed benzene ring. Since polymerization proceeds via the ortho or para positions, when Y is at the ortho or para position, at least one of Y and Z must be a hydrogen atom or Z must form said condensed benzene ring.

As discussed above, the most useful phenols which can be polymerized for use in the phenolic developer resins of the present invention are characterized in that they are para-substituted. Phenols which are not para-substituted tend generally to be too reactive and to generate very highly crosslinked compounds which may not be oil-soluble and which may not have good color developing properties. Thus, the phenols which are preferred for use in the phenolic developer resins of the present invention are represented by the formula (IV):

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(IV)

where Y is selected from the group consisting of an alkyl group, an aryl group, a phenylalkyl group, a COOR group, a -NR₁R₂ group, and a halogen atom, and Z is a hydrogen atom, a halogen atom, an alkyl group, an aryl group, a phenylalkyl group, or a -COOR group, or Z in conjunction with the adjacent meta position forms a condensed benzene ring.

Otherwise, the phenol adds as a terminal group as discussed below. At the para position, alkyl groups have a tendency to slow the reaction. The reaction appears to proceed best with a para substituted aryl group.

A single phenol or a mixture of phenols may be used in the process of the present invention. In certain applications, it may be desirable to produce phenolic resins having certain terminal groups. This can be accomplished by reacting certain phenols in which the Y substituent is the para position and Y and Z are other than hydrogen or a condensed benzene ring. In this case, the resin contains the Z substituent as a terminal group since the polymerization proceeds via a hydrogen abstraction at the ortho position. Consequently, when the phenol is para-substituted, the latter Z-substituted phenols are typically

used in a mixture with other phenols in which at least one of Y and Z is a hydrogen atom or Z is a condensed ring to provide copolymers. When the para position is unsubstituted, polymerization proceeds via the ortho and/or para position and the latter Z-substituted phenols can be incorporated mid-chain.

The alkyl group represented by Y and Z may contain up to 10 carbon atoms and include such alkyl groups as t-butyl, n-butyl, octyl, nonyl, etc. When R, R₁, and R₂ represent an alkyl group, it is typically a lower alkyl group having 1 to 4 carbon atoms.

Representative examples of alkoxy groups for Y and/or Z have 1 to 10 carbon atoms and include methoxy and ethoxy. When Y or Z is an aryl group, it is typically a phenyl group or substituted phenyl group such as a halogen-substituted phenyl group, an alkyl-substituted phenyl or a phenol group such as a 4'-phenol group.

Examples of a halogen atom include fluorine, chlorine, bromine and iodine.

Representative examples of phenylalkyl groups include benzyl, isopropylidene phenyl, butylidene phenyl, isopropylidene-4'-phenol, and butylidene-4'-phenol.

Specific examples of phenols which can be polymerized in accordance with the process of the present invention are phenol 4-t-butylphenol, 4-n-butylphenol, 4-ethylphenol, cresol, p-phenylphenol, p-octylphenol, p-nonylphenol, p-hydroxybenzoic acid, 4-hydroxynaphthoic acid, p,p'-biphenol, 4-aminosalicylic acid, salicylic

acid, methyl salicylate, ethyl salicylate,
4,4'-isopropylidenediphenol, ethyl
4-hydroxybenzoate, etc.

The phenolic developer resins of the present invention are represented by the formula (I) above and more preferably, by the formula (II) above. The phenolic resins can be homopolymers or copolymers, i.e., the individual Y or Z groups in a given phenolic developer resin may be the same or different and the Y groups may be located at different positions in accordance with the formula (I).

The developers of the present invention may range from about 500 to 5000 in molecular (number average) and preferably range from about 1000 to 3000. The developer resins are often mixtures of dimers, trimers, and higher molecular weight oligomers. The molecular weight distribution of the resin will vary depending upon the nature of the phenol and the reaction conditions. Usually, the major part of the resin (i.e., greater than 50% by weight of the resin) is trimer or higher molecular weight compound, i.e., n is greater than 2 in formulae (I) and (II).

The phenolic developer resins may be metal-modified in a manner analogous to novolak developer resins to improve their reaction with color precursors and thereby improve the density and fastness of the image. For example, the phenolic developer resins can be modified by reaction with a salt of a metal selected from the group consisting of copper, zinc, cadmium, aluminum, indium, tin, chromium, cobalt, and nickel.

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This modification can be made in an otherwise known manner. One method is by mixing and melting the resin with an alkanoate salt such as zinc propionate, zinc acetate, or zinc formate in the presence of an ammonium compound such as ammonium carbonate or ammonium acetate. The practice described in U.S. Patent No. 4,173,684 can also be used.

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The zinc-modified phenolic developer resins can also be formed by reacting zinc oxide or zinc carbonate and ammonium benzoate or ammonium formate with the resins in a manner analogous to the teachings in U.S. Patent No. 4,165,102 and 4,165,103. Alternatively, the zinc-modified phenolic developer resins can be prepared by reaction with zinc chloride as shown in the examples below.

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The metal content of the metal-modified phenolic developer resins should be more than 0.5 percent by weight and may range up to 15 percent by weight. Usually, a range of about 1.5 to 5 percent by weight is used.

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In addition, to chemically modifying the phenolic developer resins as described above, other means conventionally used in the art to improve the developing ability of phenolic developer resins, can be used in conjunction with the phenolic developer resins of the present invention. For example, acidic metal salts can be incorporated into coatings of the phenolic developer resins as described in U.S. Patent Nos. 3,516,845 and 3,723,156. The phenolic developer resins of the present invention can also be used

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in combination with other phenolic developer resins or compounds and need not be used alone.

Recording materials can be prepared in a conventional manner. To provide a developer sheet, the phenolic developer resin may be dissolved in an appropriate solvent (typically acetone) and applied to the surface of the paper by blade or roll coating or the like. Alternatively, the developer resin may be used in the form of a resin grind analogous to the resin grinds described in U.S Patent No. 3,924,027 to Saito et al. For example, the resin may be pulverized and mixed with an organic high molecular compound such as starch or styrene-butadiene latex. This mixture is dispersed in water or a solvent that does not readily dissolve the phenolic developer resin or the high molecular compound and coated on an appropriate support.

The developer resin is usually applied in an amount of about 0.2 to 0.4 lbs. of resin/1300 sq. ft. (solids).

Where a self-contained recording material is desired, a mixture of the phenolic developer resin and microcapsules containing the developer, can be coated upon a support as one layer or the developer and the microcapsules, can be applied in separate layers. For the preparation of photo-sensitive recording materials, see U.S. Patent Nos. 4,399,209 and 4,440,846 which are incorporated herein by reference.

The invention is illustrated in more detail by the following non-limiting examples.

Example I

30 mg of Sigma Type I horseradish peroxidase dissolved in 30 ml of 0.1 N potassium phosphate buffer, pH 9.0, 1.5 g of p-phenylphenol dissolved in 40 ml of ethanol and 12 ml of 3% hydrogen peroxide were each added to a dropping funnel. The dropping funnels were connected to a three-necked 300 ml round-bottom flask containing 100 ml of the phosphate buffer. While stirring constantly, the reagents were added drop-wise into the reaction flask. The reaction was allowed to proceed for ten minutes after the addition of the reagents. The product was collected by filtration and examined by thin layer chromatography.

Example II

300 milligrams of Sigma Type I horse-radish peroxidase dissolved in 200 ml of 0.1 N potassium phosphate buffer, pH 9.0 and 8.3 g of p-phenylphenol with 6.7 g of salicylic acid dissolved in 200 ml of ethanol were each added to a dropping funnel. The dropping funnels were connected to a two-liter three-necked round-bottom flask containing 30 ml of 3% hydrogen peroxide dissolved in one liter of phosphate buffer. While stirring constantly, the reagents were added drop-wise to the reaction flask. The reaction was allowed to proceed for 15 mins. after the addition of the reagents. The product was collected by filtration and examined by thin layer chromatography.

The above product was air dried and redissolved in 100 ml ethanol containing 18.5 g of 1 N sodium hydroxide. To this, a solution of 100 ml

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water, 2 g zinc chloride and 1 ml of concentrated hydrochloric acid was added drop-wise. The pH was readjusted with 1 N sodium hydroxide until a precipitate formed and the product was collected by filtration.

5 Example III

10 30 milligrams of Sigma Type I horseradish peroxidase dissolved in 20 ml of 0.1 N potassium phosphate buffer, pH 9.0 and 1.5 g of 1-naphthol dissolved in 20 ml of ethanol were each added to a dropping funnel. The dropping funnels were connected to a 300 ml three-necked round-bottom flask containing 3 ml of 3% hydrogen peroxide dissolved in 100 ml of the phosphate buffer. While stirring constantly, the reagents were added drop-wise to the reaction flask. The reaction was allowed to proceed for 10 mins. after the addition of the reagents. The product was collected by filtration and analyzed by thin layer chromatography.

20 Example IV

25 30 milligrams of Sigma Type I horseradish peroxidase dissolved in 30 ml of 0.1 N potassium phosphate buffer, pH 9.0, 1.2 g of p-phenylphenol with 0.3 g of 4-aminosalicylic acid dissolved in 40 ml of ethanol and 12 ml of 3% hydrogen peroxide were each added to a dropping funnel. The dropping funnels were connected to a 300 ml three-necked round-bottom flask containing 100 ml of phosphate buffer. While stirring constantly, the reagents were added drop-wise to the reaction flask. The reaction was allowed to proceed for 15 mins. after the addition of the reagents. The product was collected by filtration and examined by thin layer chromatography.

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Example V

30 milligrams of Sigma Type I horseradish peroxidase dissolved in 30 ml of 0.1 N potassium phosphate buffer, pH 9.0 and 12 ml of 3% hydrogen peroxide were each added to a dropping funnel.
5 The dropping funnels were connected to a 500 ml three-necked round-bottom flask containing 6.67 g of bisphenol A dissolved in 100 ml ethanol and 174 ml of the phosphate buffer. While stirring constantly, the reagents were added drop-wise to the reaction flask. The reaction was allowed to proceed for 30 mins. after the addition of the reagents. The viscous organic phase containing product was collected from a separatory funnel and
10 was examined by thin layer chromatography.
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Example VI

10 g of p-phenylphenol with five grams of ethyl salicylate dissolved in 400 ml of ethanol, 120 ml of 3% hydrogen peroxide dissolved in 80 ml of 0.1 N potassium phosphate buffer, pH 9.0 and 120 mg of Sigma Type I horseradish peroxidase dissolved in 200 ml of the phosphate buffer were each added to Erlenmeyer flasks. While stirring constantly, the reagents were added drop-wise to a
20 two-liter round-bottom flask using a peristaltic pump.
25

The reaction was allowed to proceed for 20 mins. after the addition of the reagents. The product was collected by filtration and examined by thin layer chromatography.
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5 grams of product dissolved in 100 ml of acetone were added to a 500 ml round-bottom flask fitted with a condenser and containing 100 ml of

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an aqueous 50% potassium hydroxide solution. This solution was heated at reflux for 3 hrs. and allowed to cool to room temperature. Two grams of zinc chloride were added and allowed to stir for 10 mins. in the reaction flask. The reaction mixture was adjusted to pH 4 and poured into 1.2 liters of vigorously stirring cold water. The product was collected by filtration and examined by thin layer chromatography.

Example VII

7 milligrams of Sigma Type I horseradish peroxidase dissolved in 80 ml of 0.05 N potassium phosphate buffer, pH 5.0 was added to a 250 ml round-bottom flask containing 5 g of 4-t-butylphenol and 5 g of p-phenylphenol dissolved in 20 ml of ethyl acetate. While stirring constantly, 135 ml of 0.8% hydrogen peroxide was added dropwise to the reaction flask. The reaction was allowed to proceed for 20 mins. after the addition of the peroxide. The organic phase containing product was collected, concentrated on a steam bath and examined by thin layer chromatography.

Example VIII

7 milligrams of Sigma Type I horseradish peroxidase dissolved in 80 ml of 0.05 N potassium phosphate buffer, pH 5.0 was added to a 250 ml round-bottom flask containing 8 g of 4-t-butylphenol and 2 g of p-phenylphenol dissolved in 20 ml of ethyl acetate. While stirring constantly, 137 ml of 0.8% hydrogen peroxide was added dropwise to the reaction flask. The reaction was allowed to proceed for 20 mins. after

the addition of the peroxide. The organic phase containing product was collected, concentrated on a steam bath and examined by thin layer chromatography.

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Example IX

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7 milligrams of Sigma Type I horseradish peroxidase dissolved in 80 ml of 0.05 N potassium phosphate buffer, pH 5.0 was added to a 150 ml round-bottom flask containing 8 g of bisphenol A and 2 g of p-phenylphenol dissolved in 20 ml of ethyl acetate. While stirring constantly, 127 ml of 0.6% hydrogen peroxide was added dropwise to the reaction flask. The reaction was allowed to proceed for 20 mins. after the addition of the peroxide. The organic phase containing product was collected, concentrated on a steam bath and examined by thin layer chromatography. This resin was also zinced by a procedure described in U.S. No. Patent 4,025,490.

20

Example X

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The ability of the resins to develop leuco dyes was tested by gravure printing a 3% solution of the resin on a strip of paper, spraying with CF detector, and determining the optical density on a MacBeth densitometer. Table I compares the optical densities of the above-mentioned experimental resins.

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<u>Resin</u>	<u>Table I</u>	
	<u>Optical Density</u>	<u>Zincated</u>
	<u>Unzincated</u>	
5 Example I	28.41	-
Example II	-	29.47
Example III	36.40	-
Example IV	30.53	-
Example V	33.61	-
10 Example VI	-	25.67
Example VII	24.79	-
Example VIII	31.41	-
Example IX	29.53	-

Having described the invention in detail and by reference to preferred embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims.

What is claimed is:

CLAIMS

- 1. A process for the preparation of a phenolic resin which comprises reacting a phenol with a peroxidase or an oxidase enzyme and a peroxide in an organic solvent containing medium to generate phenolic radicals which react to form a phenolic resin.
- 5
2. The process of claim 1 wherein said enzyme is reacted in an amount of about 10 milligrams to 5 grams per 100 grams phenol.
3. The process of claim 2 wherein said process comprises dissolving said phenol in an organic solvent, dissolving said enzyme in water and mixing said solutions.
4. The process of claim 3 wherein said enzyme is horseradish peroxidase.
5. The process of claim 1 wherein said process further comprises forming a mixture of said phenol and said enzyme, and gradually adding said peroxide to said mixture.
6. The process of claim 1 wherein said peroxide is hydrogen peroxide.
7. The process of claim 1 wherein said reaction proceeds at a temperature of about 0 to 40°C.

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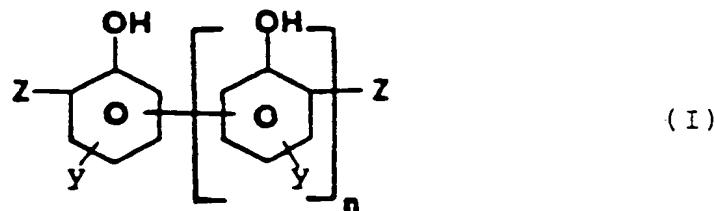
8. The process of claim 1 wherein the concentration of said phenol in said solvent is about 1 to 100 g per 100 ml solvent.

9. The process of claim 1 wherein said reaction is carried out at a pH in the range of about 4 to 12.

10. The process of claim 1 wherein said phenolic resin has a molecular weight of approximately 1000 to 15,000.

11. The process of claim 1 wherein said phenolic resin has a molecular weight of approximately 500 to 5000.

12. A developer sheet comprising a support having a color developer on one surface thereof, said developer being capable of reacting with an electron-donating color precursor and producing a visible image and being formaldehyde-free phenolic developer resin represented by the formula (I):

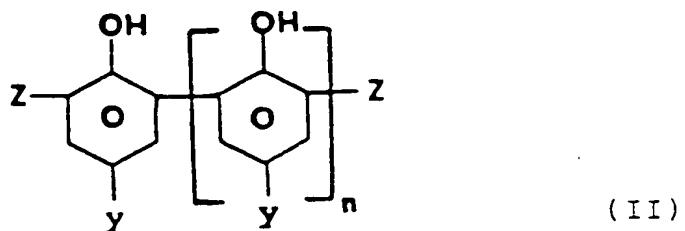


where n is an integer greater than or equal to 2, the phenolic units of the resin are directly bonded to one another through positions ortho or para to the hydroxy group, Y is present at a position meta

or para to the hydroxy group and is selected from the group consisting of an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, an allyl group, a group of the formula -COOR where R is a hydrogen atom, a phenylalkyl group or an alkyl group, an amino group of the formula -NR₁R₂ where R₁ and R₂ are the same or different and represent a hydrogen atom or an alkyl group, and Z is a hydrogen atom, an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, or a -COOR group, or Z in conjunction with the adjacent meta position forms a condensed benzene ring; or a metal-modified, formaldehyde-free phenolic developer resin obtained by reacting said developer resin with a metal salt.

13. The developer sheet of claim 12 wherein said developer resin has a molecular weight of approximately 500 to 5000.

14. The developer sheet of claim 12 wherein said developer resin is represented by the formula (II):



5 where n, Y and Z are defined as in claim 12.

15. The developer sheet of claim 14 wherein said resin has a molecular weight of about 1000 to 3000.

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16. The developer sheet of claim 15 wherein Z is a hydrogen atom.

17. The developer sheet of claim 16 wherein Y is an alkyl group, a phenyl group, or a phenylalkyl group.

18. The developer sheet of claim 12 wherein said color developer comprises said developer resin.

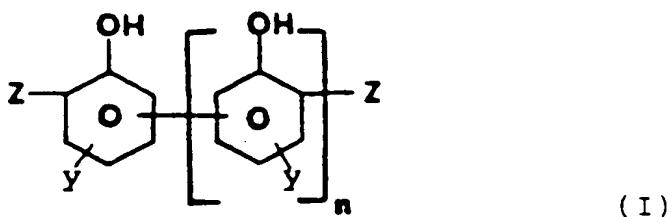
19. The developer sheet of claim 12 wherein said color developer comprises said metal-modified developer resin.

20. The developer sheet of claim 19 wherein said metal is zinc.

21. A recording material comprising a support having a layer of microcapsules on one surface thereof and having a color developer co-deposited on said surface of said support with said microcapsules or deposited on the surface of a separate support, said microcapsules containing in the internal phase a substantially colorless electron-donating compound, said color developer being capable of reacting with said electron-donating compound and generating a visible image and being a formaldehyde-free phenolic developer resin represented by the formula (I):

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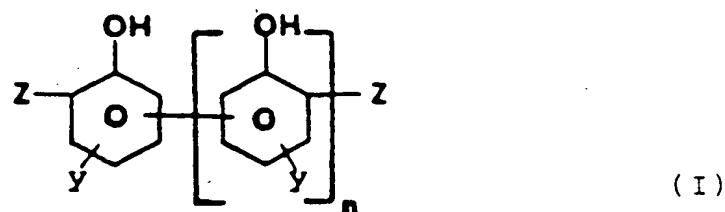
10



where n is an integer greater than or equal to 2,
15 the phenolic units of the resin are directly bonded
to one another through positions ortho or para to
the hydroxyl group, Y is present at a position
meta or para to the hydroxyl group and is selected
from the group consisting of an alkyl group, a
20 halogen atom, an aryl group, a phenylalkyl group,
an allyl group, a carboxyl group of the formula
-COOR, where R is a hydrogen atom, an alkyl group
or a phenylalkyl group, an amino group of the
formula -NR₁R₂ where R₁ and R₂ are the
25 same or different and represent a hydrogen atom or
an alkyl group, and Z is a hydrogen atom, an alkyl
group, a halogen atom, an aryl group, a phenylalkyl
group, or a -COOR group, or Z in conjunction with
the adjacent meta position forms a condensed
30 benzene ring; or a metal-modified, formaldehyde-
free phenolic developer resin obtained by reacting
said developer resin with a metal salt.

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22. A resin of the formula (I):



where n is an integer greater than or equal to 2, the phenolic units of the resin are directly bonded to one another through positions ortho or para to the hydroxyl group, Y is present at a position meta or para to the hydroxy group and is selected from the group consisting of an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, an allyl group, a carboxyl group of the formula -COOR, where R is a hydrogen atom, an alkyl group or a phenylalkyl group, an amino group of the formula -NR₁R₂ where R₁ and R₂ are the same or different and represent a hydrogen atom or an alkyl group, and Z is a hydrogen atom, an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, or a -COOR group, or Z in conjunction with the adjacent meta position forms a condensed benzene ring; or a metal-modified, formaldehyde-free phenolic developer resin obtained by reacting said developer resin with a metal salt.

AMENDED CLAIMS

[received by the International Bureau on 25 February 1987 (25.02.87);
original claim 8 cancelled; claims 1,12 and 21 amended; 23-32 new; other claims
unchanged (6 pages)]

1. A process for the preparation of a phenolic resin which comprises reacting about 1 to 100 gram/100 ml of a phenol with a peroxidase or an oxidase enzyme and a peroxide in an organic solvent containing medium to generate phenolic radicals which react to form a phenolic resin and recovering said phenolic resin.

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2. The process of claim 1 wherein said enzyme is reacted in an amount of about 10 milligrams to 5 grams per 100 grams phenol.

3. The process of claim 2 wherein said process comprises dissolving said phenol in an organic solvent, dissolving said enzyme in water and mixing said solutions.

4. The process of claim 3 wherein said enzyme is horseradish peroxidase.

5. The process of claim 1 wherein said process further comprises forming a mixture of said phenol and said enzyme, and gradually adding said peroxide to said mixture.

6. The process of claim 1 wherein said peroxide is hydrogen peroxide.

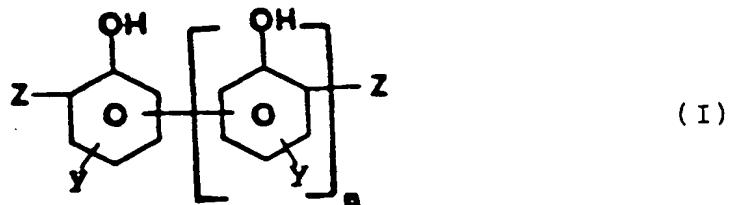
7. The process of claim 1 wherein said reaction proceeds at a temperature of about 0 to 40°C.

9. The process of claim 1 wherein said reaction is carried out at a pH in the range of about 4 to 12.

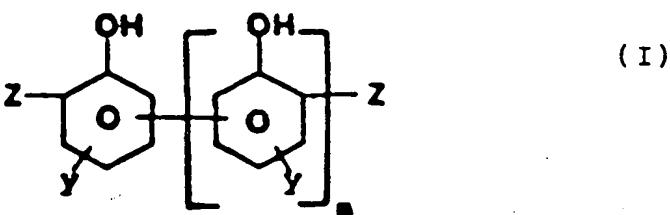
10. The process of claim 1 wherein said phenolic resin has a molecular weight of approximately 1,000 to 15,000.

11. The process of claim 1 wherein said phenolic resin has a molecular weight of approximately 500 to 5,000.

12. A developer sheet comprising a support having a color developer on one surface thereof, said developer being capable of reacting with an electron-donating color precursor and producing a visible image and being formaldehyde-free phenolic developer resin represented by the formula (I):



wherein n is greater than or equal to 2, the phenolic units of the resin are directly bonded to one another through positions ortho or para to the hydroxy group, Y is present at a position meta



where n is greater than or equal to 2, the phenolic units of the resin are directly bonded to one another through positions ortho or para to the hydroxyl group, Y is present at a position meta or para to the hydroxy group and is selected from the group consisting of an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, an allyl group, a carboxyl group of the formula -COOR, where R is a hydrogen atom, an alkyl group or a phenylalkyl group, an amino group of the formula -NR₁R₂ where R₁ and R₂ are the same or different and represent a hydrogen atom or an alkyl group, and Z is a hydrogen atom, an alkyl group, a halogen atom, an aryl group, a phenylalkyl group, or a -COOR group, or Z in conjunction with the adjacent meta position forms a condensed benzene ring; or a metal-modified, formaldehyde-free phenolic developer resin obtained by reacting said developer resin with a metal salt.

23. The process of claim 1 wherein said organic solvent containing medium includes a first aqueous phase and a second water immiscible phase and said process includes the additional steps of recovering said phenolic resin from said water immiscible phase and recovering said enzyme from said aqueous phase.

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24. The process of claim 1 wherein said organic solvent containing medium is an organic aqueous-medium having a water:organic volumetric ratio in the range of 1:2 to 2:1.

25. The developer sheet of claim 12 wherein at least 50% of said developer resin is trimer or higher molecular weight resin.

26. The developer sheet of claim 12 wherein said developer resin is prepared by reacting a phenol with a peroxide-peroxidase enzyme system.

27. The developer sheet of claim 26 wherein said phenol is selected from the group consisting of 4-t-butylphenol, 4-n-butylphenol,
5 4-ethylphenol, cresol, p-phenylphenol, p-octylphenol, p-nonylphenol, p-hydroxybenzoic acid, 4-hydroxynaphthoic acid, p,p'-biphenol, 4-aminosalicylic acid, salicylic acid, methyl salicylate, ethyl salicylate, 4,4'-isopropylidenediphenol and ethyl
10 4-hydroxybenzoate, etc.

28. The developer sheet of claim 14 wherein Z is a hydrogen atom and Y is in the para position and is a 2-(4'-phenol)isopropyl group.

29. The recording material of claim 21 wherein at least 50% of said developer resin is trimer or higher molecular weight resin.

30. The recording material of claim 21 wherein said developer resin is prepared by reacting a phenol with a peroxide-peroxidase enzyme system.

31. The recording material of claim 30 wherein said phenol is selected from the group consisting of 4-t-butylphenol, 4-n-butylphenol, 4-ethylphenol, cresol, p-phenylphenol, 5 p-octylphenol, p-nonylphenol, p-hydroxybenzoic acid, 4-hydroxynaphthoic acid, p,p'-biphenol, 4-aminosalicylic acid, salicylic acid, methyl salicylate, ethyl salicylate, 4,4'-isopropylidenediphenol and ethyl 10 4-hydroxybenzoate, etc.

32. The recording material of claim 21 wherein Z is a hydrogen atom and Y is in the para position and is a 2-(4'-phenol) isopropyl group.

STATEMENT UNDER ARTICLE 19

The purpose of this Statement is to provide a brief explanation of the accompanying six claim replacement sheets of the above-identified application.

Claim 1 as filed has been amended to define the concentrations of phenol reacted in accordance with the inventive process. This concentration was the subject of claim 8 as filed and thus, claim 8 has been cancelled. Claim 12 as filed has been amended to delete "an integer" from line 7; support for this amendment exists on page 15, line 24. Claim 21 as filed has been amended to delete "an integer" from line 14; support for this amendment exists on page 15, line 24.

In addition, claims 23 and 24 have been added which are respectfully directed to the embodiments of the invention in which the phenol and enzyme are recovered from separate phases of the reaction medium and the reaction medium is an organic-aqueous medium having a specified volumetric ratio. Support for claim 23 exists on page 5, lines 5-13. Support for claim 24 exists on page 9, lines 27-34. Claim 25-32 have also been added. Support for claims 25 and 29 exists on page 15, lines 21-24. Support for claims 26 and 30 exists on page 3, lines 28-32. Support for claims 27 and 31 exists on page 14, lines 27-33 to page 15, lines 1-3. Support for claims 28 and 32 exists in Example V on page 20 and on page 15, line 2 by reference to 4,4'-isopropylidenediphenol.

The foregoing amendments parallel amendments made during the prosecution of the two U.S. priority documents and since they are clearly supported by the specification, do not raise a question of new matter.

INTERNATIONAL SEARCH REPORT

International Application No PCT/US86/02259

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all):

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(4) B41M 5/22; C08G 65/38, 65/44 528/86, 210, 212, 214, 215
US CL 346/210, 211, 212, 216, 217, 225; 427/150, 151, 152; 435/127, 156; 525/506; 527/200;

II. FIELDS SEARCHED

Minimum Documentation Searched

Classification System	Classification Symbols
U.S.	346/210,211,212,216,217,225;427/150,151,152;435/127,156;
<u>525/506;527/200;528/86,210,212,214,215</u>	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 5	

III. DOCUMENTS CONSIDERED TO BE RELEVANT¹⁴

Category • Citation of Document, ¹⁶ with indication, where appropriate, of the relevant passages ¹⁷ Relevant to Claim No. ¹⁸

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Published 1980.

Y DE,A, 3,430,735 (CIBA-GEIGY) Published 07 MARCH 1985. 1-11,22

Y Danner, Archives of Biochemistry and Biophysics, 156, 759-763, Published 1973. 1-11,22

Y ALBERTI, Biological Detoxification, 349-352, Published 1982. 1-11,22

X SINGH, Biotechnology Letters, 7, 663-664, Published 1985. 1-11,22

A US,A, 4,165,102 (BODMER) Published 21 AUGUST 1979. 12-21
 ²⁸

A US,A, 4,165,103 (BODMER) Published 21 AUGUST 1979. 12-21

A US,A, 4,025,490 (WEAVER) Published 24 MAY 1977. 12-21

A Bollag, Pesticide Biochemistry and Physiology, 23, 261-272, Published 1985. 1-11,22

- Special categories of cited documents:¹³

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or

"P" document published prior to the international filing date but later than the priority date claimed

later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search :

Date of Mailing of this International Search Report:

05 JAN 1987

03 DECEMBER 1986

Signature of Authorized Officer ²⁰

Howard F. Schain
HOWARD F. SCHAIN

Form BCT/US-A/210 (second sheet) (October 1981)